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Development of scientific explanation ability of eleventh-grade students through science drama-based learning

Aganit Seepootorn

Department General Science, Faculty Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand

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Abstract

The research aims to develop scientific explanation ability of eleventh-grade students through science drama-based learning based on the concept of edutainment with five main steps as follows: (1) orienting and questioning, (2) investigating, (3) strengthening understanding/ reflecting, (4) developing the drama, and (5) communicating/ reflecting. The research objectives consisted of: (1) To study the approaches to science drama-based learning that develop scientific explanation ability; (2) To compare scientific explanation ability before and after learning; and (3) To study students' satisfaction with science drama-based learning. The research model was pre-experimental research using quantitative and qualitative data to show the results of science drama-based learning. The research participants were 29 eleventh grade students. The research instruments consisted of: (1) a science drama-based learning lesson plan; (2) a scientific explanation ability test; (3) interviewing form for a reflection about science drama-based learning and the scientific explanation ability; and (4) the satisfaction assessment form towards science drama-based learning. The results showed that: (1) the mean scores from scientific explanation ability test after learning were significantly higher than before at the 0.01 level ($t = 8.28$, $p < .01$); and (2) the satisfaction level of the students towards the overall science drama-based learning was at the highest level. (Mean score = 4.53, $SD = 0.59$). The results revealed that science drama-based learning could develop students' scientific explanation abilities. However, students lacked proficiency in reasoning that explains the relationship between evidence and conclusion (claim), referring to sufficient and appropriate evidence for the conclusion.

E-mail address: sriputon@hotmail.com.

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Introduction

Scientific explanations are the basis for the quest for knowledge. It is an explanation to reflect the results of observations and empirical experiments by identifying the causes and effects of natural phenomena and showing a cause-and-effect relationship consistent with the evidence. It must be public and changeable if it is considered by the scientific community (Berland & Reiser, 2008; Kuhn & Reiser, 2005; National Research Council [NRC], 1996). It is an explanation to support a person's idea or belief (Berland & Reiser, 2008; Beyer & Davis, 2008; Chin & Brown, 2000; McNeill & Krajcik, 2006; Osborne & Patterson, 2011; Sampson & Clark, 2011), to convince others to understand by identifying evidence and connecting scientific ideas to phenomena to support explanations and explains how things happen by using evidence and reasoning to support the explanation (Gagnon & Abell, 2008; McNeill & Krajcik, 2006; Reiser et al., 2012; Sandoval & Reiser, 2004). It consists of (1) conclusion (claim), (2) evidence, and (3) reasoning (Berland & Reiser, 2008; Brunsell, 2012; BSCS Center for Professional Development, 2008; Kuhn & Reiser, 2005; McNeill & Krajcik, 2008; Ruiz-Primo et al., 2010; Sampson & Clark, 2011).

Organizing learning to achieve the goal of teaching science is challenging. Teachers need to develop the way they manage learning to be interesting. Entertainment education (Edutainment) in the form of Drama in Education (DIE) is another option that is currently of interest. It is consistent with the direction of Thai education in various contexts (Jaidee & Theparak, 2019). Learning and teaching by integrating drama with science content is called science drama. It is a new dimension in presenting science stories. Moreover, it makes learning enjoyable and see a clear picture of science, which play a role and importance in life. Science educators who use drama as a learning tool agree that this body of knowledge has been extended to a broader dimension than in the classroom because science drama performances help students learn and retain knowledge from participating in activities (BouJaoude et al., 2005; Chamchoy, 2019; Dorion, 2009; Pasavano, 2013). Students have been a practitioner and speak to present knowledge Ideas and attitudes. However, science drama performances might not be suitable for complex or experimental concepts. Science drama performances are characterized by active learning, which makes students remember what they have learned up to 90 percent compared to other activities (Paoguntrakorn, 2013). It could be used for students of different ages and abilities and arouse interest in scientific situations which affect learning achievement and learning interest (Abed, 2016; BouJaoude et al., 2005; Bracha, 2007; Gascon, 2019; Maharaj-Sharma, 2017; Najami et al., 2019; Ong et al., 2020).

This research presented the concept of science drama-based learning based on the concept of entertainment education (Edutainment) by integrating scientific explanation with the integrative Drama-Inquiry Learning (IDI) (Kolovou & Kim, 2020), which was an integrative drama-learning model for use in science classrooms. It consisted of 5 steps: (1) Orienting and Questioning, (2) Investigating, (3) Strengthening Understanding/ Reflecting, (4) Developing the Drama, and (5) Communicating/ Reflecting together with the content of climate change. The scientific explanation is inserted in step 3 in order to strengthen the process of the transfer of understanding in the drama context by inserting the scientific explanation components. To support student in expressing the scientific opinions and explanation and to practice and transfer in a variety of contexts, the learners have to understand both the scientific explanation method and the scientific content knowledge, or the scientific concept (Becker, 2014; Metz, 2000; Sadler, 2004; Walker et al., 2012).

Therefore, the research study conducted a learning approach that integrates educational drama with science content. It is a science drama-based learning to develop students' scientific explanation ability. It also encourages students to learn according to their interests and to show their full potential. Moreover, the student could adapt situations or events occurring in everyday life and social issues related to scientific knowledge to create a story according to the imagination. They could connect to facts, conclusions, ideas, and scientific evidence that develops the scientific explanation ability. It is a fundamental skill in the quest for scientific knowledge leading to the development of holistic learners affecting the understanding of both the content and leading the practice of having durable knowledge and enjoying learning science (Adey & Shayer, 1994; Bracha, 2007; Metz, 2000; Pasavano, 2013; Sadler, 2004).

Literature Review

Drama-based learning (DBL) has been implemented in Thai classrooms. It mostly offers students to investigate information, create a story and provide production and make distributions (Chamchoy, 2019; Jaidee & Theparak, 2019; Phaokantakorn, 2013). Only one learning model of

Science Drama-based Learning was found, Kolovou and Kim (2020) implementing an integrated drama learning model in science classrooms, which suggested the Integrative Drama-Inquiry (IDI) learning model as shown in Figure 1. Integrative Drama-Inquiry (IDI) learning model consists of 6 steps: (1) Orienting, (2) Questioning, (3) Investigating, (4) Strengthening Understanding/ Reflecting, (5) Developing the Drama, and (6) Communicating/ Reflecting. The researcher had defined the roles of teachers and students in each step as follows:

1. Orienting: Teachers describe relevant content through methods and media such as lectures, readings, videos, scientific inventions, or specific events that focus attention and introduction to scientific problems, where students brainstorm to practice asking possible questions about problems from science-drama examples and used them as a guideline for studying and researching scientific concepts that were interesting or they would like to present.

2. Questioning: Teachers explain about asking questions or identifying problems with scientific issues and identify what you need to know by narrowing down the questions and identifying scientific problems to explore in accordance with the orientation of the character/role perspective to stimulate the need to seek scientific knowledge. Students work together to practice asking questions and identifying relevant scientific problems and are ready to practice science drama script writing by adding additional issues of interest.

3. Investigating: Teachers describe relevant content, give advice and assign students to work on additional research on issues of interest from various sources in order to obtain complete and accurate content in writing a science drama script outline.

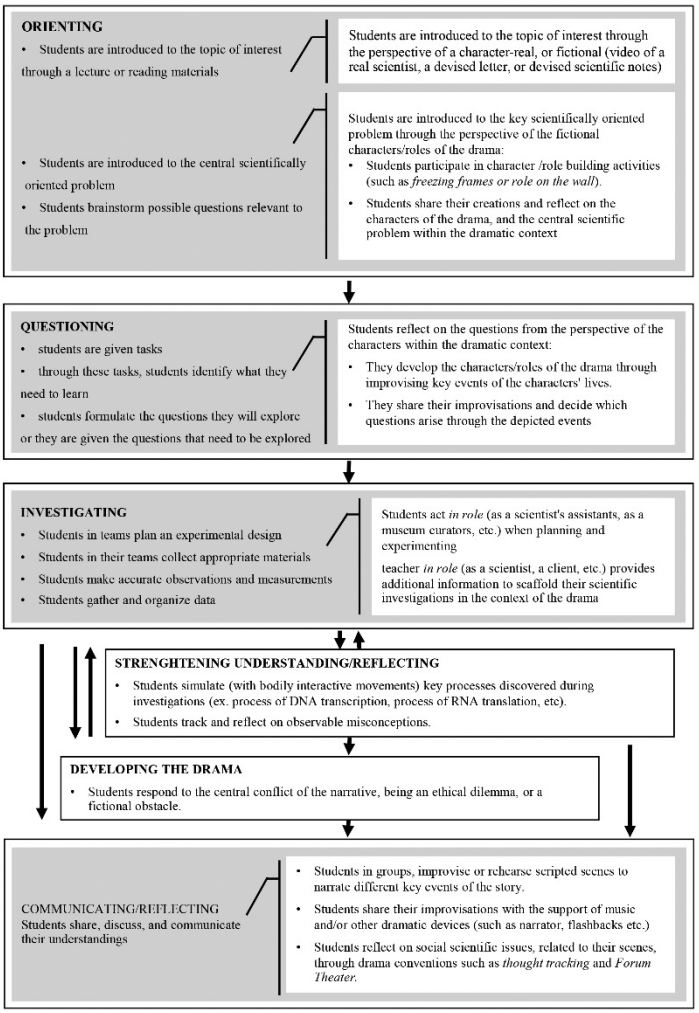

Figure 1 Integrative Drama-Inquiry (IDI) learning model
Source: Kolovou and Kim (2020)

4. Strengthening Understanding/Reflecting: Teachers describe relevant content and provide additional lectures on the scientific explanation components, consult and assign students to work together to analyze, discuss, and summarize concepts different from science drama by considering the evidence and arguments that support the conclusion from the character's idea. Students together write a science drama script that reflects science concepts and covers the scientific explanation components. And, teachers give advice on the validity of scientific content, consistency with the scientific explanation components, and suggest improvements for the writing of a complete science drama script.

5. Developing the Drama: Teachers assign students to write plays based on scientific concepts they want to present. It covers the scientific explanation components. Students present complete dramatization progression and bring the science drama to create animation media.

6. Communicating/Reflecting: Teachers ask students to watch the animation media while giving them a reflection on the science concepts they would like to present, the scientific knowledge gained, and the scientific explanation components.

In this research, the researcher used a teaching model based on the integrative drama learning model applied in the science classroom based on the concept of Kolovou & Kim (2020), as there were clear steps appropriate to the scientific process to lead to the development of scientific explanation component including claim, evidence, and reasoning (BSCS Center for Professional Development, 2008; Brunsell, 2012; McNeill et al., 2006; Ruiz-Primo et al., 2010; Sampson & Clark, 2011). Step 1 and 2 were merged because both steps require continuous thinking. Therefore, they could not be separated from each other. The scientific explanation is inserted in step 3 (Strengthening Understanding/Reflecting). In this step, students would have opportunities to work together to analyze, discuss and summarize ideas from science plays, analyze issues of interest, find out more to reflect the content. They are engaged to present, and write a science drama that accurately reflects scientific concepts and cover the scientific explanation components.

Methodology

This research was pre-experimental research. It emphasized collecting both qualitative and quantitative data. The research aimed to study the development of scientific explanation ability (a dependent variable). The research also used qualitative data to reflect the events and reflections (Johns, 2000) that occurred during science drama-based learning (an independent variable).

Participants

The research participants were comprised of 29 students in eleventh grade. Students were studying science-mathematics study plan in the second semester of the academic year 2021 in Nakhon Pathom Province.

Research Instruments and Data Analysis

1. Science drama-based learning lesson plan: The researcher formulated guidelines for the development of scientific explanation ability by organizing science drama-based learning, together with teaching climate change content modifying from the Integrative Drama-Inquiry (IDI) model (Kolovou & Kim, 2020). It had suggested an IDI model that had been applied in the science classroom and had clear steps appropriate to the scientific process that would lead to the development of scientific explanation components. And, the researcher developed the science drama-based learning lesson plan for the development of scientific explanation ability in 6 weeks (2 hours per week). Weeks 1–5 were organized in online learning, and the 6th week organized activities in on-site learning in order of steps as shown in Table 1.

Table 1 Science drama-based learning lesson plan for 6 weeks (2 hours per week)

Step	Learning Activities
Step 1: Orienting and Questioning (120 minutes)	1. The teacher proposed to students the learning objective about climate change and factors affecting climate change. 2. The teacher divided students into three groups. Each group had 9–10 students. Then, the teacher showed them a video of the youth science drama "Doo Doo, Look What People Do, Why You Can Do This to the World?" The story is told by animals such as frogs, rabbits, elephants, turtles, owls, and white bears that tried to understand the causes of global change, which humans called "global warming", which affected the well-being of all life on earth (Institute for the Promotion of Teaching Science and Technology, 2008). 3. Each group of students analyzed the play, practiced asking questions and identifying scientific issues related to climate change, and sent representatives to present.

Table 1 Continued

Step	Learning Activities
	4. The teacher asked each group of students to define problems from everyday phenomena related to climate change, such as global turbulence, greenhouse gas emissions, drought, forest fires, PM 2.5 dust, and the impact of climate change to define the scope of science content of interest. 5. Each group of students practiced writing the play by adding more roles from issues of interest and try acting according to the role of that character. 6. The teacher assigned tasks to each group of students for further study.
Step 2: Investigating (120 minutes)	1. The teacher provided examples of evidence concerning geology. 2. Each group of students jointly researched the issues of interest from various sources in order to obtain accurate and complete content and defined the outline of the play. 3. Each group of students presented the results of their studies.
Step 3: Strengthening Understanding/ Reflecting) (240 minutes)	1. The teacher provided the basic ideas of scientific explanations, consisting of claim, evidence and reasoning. 2. Each group of students analyzed, discussed, and summarized the different concepts of the characters from the documentary science play "Doo Doo, Look What People Do, Why You Can Do This to the World?", considering evidence and reasoning to support the conclusion from the concept of the character. 3. Each group of students analyzed the issues of interest and searched for additional information to reflect the content they would like to present and covering the scientific explanatory component. 4. Each group of students together wrote a complete play. It reflected the scientific concepts that were valid and covered the scientific explanatory component. 5. The teacher observed the group activities and advised what each group should pay special attention to, such as the scientific idea to be presented, scientific explanation or role-playing, etc.
Stage 4: Developing the Drama (120 minutes)	1. Each group of students presented their progress in writing the play that had improvements according to recommendations 2. Each group of students brought the complete drama to make an animation medium.
Step 5: Communicating/ Reflecting) (120 minutes)	1. Students watched animation media. 2. Students together reflected, discussed and exchanged knowledge from watching the animation of each group in the issue of conveying the story consistent with the science concepts to be presented, scientific knowledge gained and scientific explanation.

2. Scientific Explanation Ability Test: It is a subject exam. Ten situations related to climate change were identified. Each situation comprised three open-ended questions (2 points for each), covering the scientific explanation component, namely, claim, evidence, and reasoning, a total of 60 points. Content accuracy was checked and revised according to the recommendations of 3 experts in the field of science education with the IOC index (Index of Item Objective Congruence: IOC) between 0.67–1.00. The experiment was applied to 23 students of eleventh-grade to determine the confidence by using Cronbach's alpha coefficient was 0.81 and was used to analyze Inter-Rater Reliability in checking answers. The researchers developed specific evaluation criteria for the scientific explanations. It was a specific scoring rubric that corresponded to ten criteria on the Scientific Explanation Test (each with three components) (McNeil & Krajcik, 2012), which was built based on an explanatory framework. According to the concept of McNeil and Krajcik (2012), the scoring criteria for each component were divided into three levels, namely, 2 points, 1 point, and 0 points. Therefore, each test had a full score of 6 points. The evaluators' scientific explanation ability scores comprised the researcher for one person and the science teacher teaching in eleventh grade (a science-mathematics study plan), for one person, a total of two people to calculate Pearson's correlation coefficient with setting statistical significance at .01. The results showed that there was a statistically significant correlation between the evaluators' scientific ability scores. The correlation coefficient was 0.76. Data were collected to compare the scientific explanation ability before and after the science drama-based learning for 2 weeks based on the mean scores from the test. Then the data were analyzed by using a t-test for dependent samples and a *t*-test for one group of data (*t*-test for one sample).

Sample examination and score answers for scientific explanation ability test

Situation: Figure 2 shows that Ultraviolet (UV) radiation from the sun travels through the atmosphere to Earth and reflects back from both the Earth's surface and the atmosphere, but there are some UV rays that can't be reflected through the atmosphere due to the presence of greenhouse gases. It has been concluded that UV radiation is one of the causes of global warming. Table 2 explains the criteria for evaluating scientific explanation abilities.

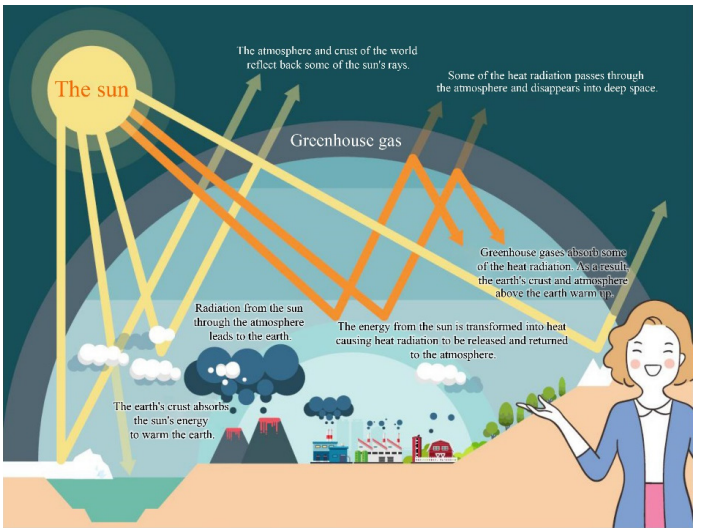

Figure 2 The greenhouse effect
Source: Department of Environmental Quality Promotion, 2020

Table 2 Criteria for evaluating scientific explanation abilities.

Component	Score level		
	0 (improvement)	1 (medium)	2 (good)
Claim: A statement or a summary that is the answer to a given question or problem.	Do not draw conclusions or draw incorrect conclusions, such as *"Agreed, because the cumulative radiation increases the temperature of the earth." (Student 43848)* *"Agreed, because some of the UV rays that cannot be reflected through are causing the world to warm up." (Student 43869)*	Draw the correct conclusion but not complete, for example *"Agreed, but not entirely correct, because irreversible UV radiation will actually cause global warming. But if the greenhouse layer is not too dense, the UV rays will be reflected normally. On Earth, it will be received in normal quantities. If so, UV is not the cause of global warming." (Student 44410)* *"Agreed, because some UV rays cannot be reflected through the layers. Atmosphere can be removed because there are greenhouse gases blocking it." (Student 44066)*	Draw accurate and complete conclusions such as *"I disagree, because UV is just an element. The main cause is greenhouse gases" (Student 45924).* *"Disagree, because more UV radiation back to the Earth's surface is a result of greenhouse gases." (Student 43717)*
Evidence: Scientific information supports a conclusion. This information must be appropriate and sufficient to support the conclusion	Not specify evidence or evidence provided is inappropriate (evidence specified does not support conclusions) such as *"Global warming" (Student 44021)* *"The temperature of the world is rising." (Student 43700)*	Identify the evidence appropriately but this is not enough to support the conclusion. Some evidence may be inappropriate, for example: *"Greenhouse gases are blocked" (Student 44277)* *"Greenhouse gases in the atmosphere" (Student 43848)*	Provide appropriate evidence and sufficient to support conclusions such as *"Greenhouse gases have an effect on absorbing and reflecting back some UV radiation and thus radiating back to the Earth's surface." (Student. 43717)*

Table 2 Continued

Component	Score level		
	0 (improvement)	1 (medium)	2 (good)
			"*Ultraviolet radiation from the Sun travels through the atmosphere to Earth and is reflected back from both the Earth's surface and the atmosphere, but some UV rays cannot be reflected through the atmosphere because there is gas. The glasshouse is blocked."* *(Student 43725)*
Reasoning: Decisions that the evidence supporting a conclusion is reasonable and sufficient based on scientific principles.	Not giving reasons or giving reasons that don't link evidence to support a conclusion, for example: *"Some of the UVs cannot be reflected through the atmosphere because of the greenhouse gas barrier."* *(Student 44021)* *"The high amount of infrared radiation that is deposited in the Earth's surface results in more global warming."* *(Student 45926)*	Provide reasons that link the evidence and supports the conclusion. Some but not enough scientific evidence is linked, for example: "*Some UVs cannot be reflected through the atmosphere because of the greenhouse gas barrier."* *(Student 43785)* *"More greenhouse gases increase the absorption and emission of UV radiation to the Earth's surface."* *(Student 44274)*	Provide evidence that links evidence that supports a conclusion. including applying appropriate and sufficient scientific principles such as *"There are greenhouse gases blocking it, making some of the UV rays that cannot be reflected through the atmosphere, one of the causes of global warming."* *(Student 44277)* *"UV radiation travels from the Sun through the atmosphere to the Earth and is reflected back by both the Earth's surface and the atmosphere. But there are greenhouse gases that absorb some of the UV rays and cause the weather to warm up."* *(Student 43725)*

1. Based on the information, do students agree with the conclusion (claim) and why?

2. What is the evidence that leads students to think so?

3. Ask students to explain how their evidence supports answer 1.

3. The satisfaction assessment form of eleventh-grade students towards science drama-based learning by using the questionnaire on a rating scale of 5 on a scale of 5 means most agree, 4 means somewhat agree, 3 means moderately agree. 2 means slightly agree, 1 means least agree. 12 questions cover 3 questions: (1) Learning management and scientific attitudes; (2) Promoting knowledge, understanding, and thinking skills; and (3) Promotion of application in daily life, number 12 items, checking the accuracy of the content and revising according to the recommendations of 3 experts in the field of science education with the IOC index between 0.67–1.00.

4. An interview form for reflection on scientific explanations in the form of open-ended questions containing 4 issues of scientific concepts and scientific explanation components, checking for content validity, and revising according to the recommendations of 3 experts in the field of science education with the IOC index between 0.67–1.00.

Results

1. The results of a study on the science drama-based learning approach enhances development of scientific explanation ability.

Results of the science drama-based learning in 5 Steps (6 weeks)

Step 1 Orienting and Questioning: In the beginning, most students did not answer questions or express opinions. Some students asked questions and addressed broad scientific problems, so teachers were encouraged by questions, gave more knowledge and examples, and called for a specific student, which made students more enthusiastic about participating in expressing opinions and answering questions. Overall, students are able to ask questions and identify scientific problems.

Step 2 Investigating: The results showed that 1 group of students from 3 groups submitted the outline of the play in advance, but it was not complete for dividing the roles and duties of the members within the group. All groups of students could determine the titles and scientific concepts they would like to present that were related to the content of climate change, such as global warming and air pollution. The drama outline of the first group of students was a comedy-drama titled "Story of the mysterious old man", Group 2 was a scientific drama titled "Return" and Group 3 was a drama titled "Help me help my earth". Groups 2 and 3 had an unclear oral presentation about the outline of the play but could visualize the story from beginning to end.

Step 3 Strengthening Understanding/ Reflecting: By inserting scientific explanation exercises, most students could conclude problem identification, and provide evidence to refer to conclusions, but they could not give a clear reason for the relationship between the evidence and the conclusion. The results of the analysis of the complete science play are shown in Table 3.

Step 4 Developing the Drama: The researcher brought the complete science drama of the students from 3 groups to create animation media, namely (1) "The story of the mysterious old man"; is a comedy-drama with a length of 4 minutes and 35 seconds. The concept is to present global warming and preventive measures; (2) "Return"; is a science-based drama with a length of 6 minutes and 13 seconds. Its presentation is on global warming and air pollution crisis; and (3) "Help me help my earth"; is a science-based drama with a length of 6 minutes and 52 second and a conceptual approach to the greenhouse gas and the Milakovich cycle.

Step 5 Communicating/ Reflecting: A total of 22 secondary school students participated in science drama-based learning activities out of a total of 29 students. The result showed that the students could identify science concepts in accordance with the science concepts in the 3-animation media they would like to present. The average score for the scientific explanation ability was 12.27, the standard deviation was 1.95, and the coefficient of variation was 0.159, reflecting that the students had a relatively high ability to explain science. However, when analyzing the scientific explanation components, the reasoning aspect had the lowest average score and less than half of the full score, which could reflect that the students were not as good at connecting evidence to scientific claims or conclusions as they could be.

Examples of discussion results, reflections, and exchange of knowledge on storytelling were consistent with the proposed science concept and the coverage of the scientific explanation components. Animated media titled Return from the science drama of the second group of students had a science concept they would like to present about the global warming crisis, air pollution, and prevention measures. After watching animation media, the students identified three scientific concepts: (1) Pollution had 14 people accounting for 64 percent; (2) Air pollution and impacts had 6 people accounting for 27 percent; and (3) Global warming had 2 people accounting for 9 percent, which corresponded to the science concept that the second group of students would like to present. As an example, the following students' scientific concepts are identified.

Table 3 The results of the analysis of the complete science play.

Results	Group 1	Group 2	Group 3
Title	The Mysterious Old Man	Return	Help Me Help My Earth
Main Concepts	Global warming and prevention methods.	Global warming crisis air pollution.	Greenhouse gases and the Milakovich cycle.
Claim:	The conversion of oil to electricity	Global warming crisis and air pollution have made it impossible for humans to live on the ground.	Combustion affects the change in global temperature.
Evidence:	1. Reducing incineration, 2. Burning waste is linked to global warming. 3. Deforestation	1. The cost of dust and various pollutants. 2. The problem of air pollution in the future	Fuel combustion, garbage incineration, and forest fires
Reasoning:	Electricity reduces combustion which causes carbon dioxide to float up into the atmosphere, but if we avoid using oil and use the electric car instead, it will not produce carbon dioxide.	Carbon monoxide, sulfur dioxide, nitrogen oxides, and dust are smaller than 10 microns caused by vehicles and industrial plants causing air pollution.	Fuel combustion, garbage burning, and forest fires also cause greenhouse gases such as carbon dioxides, affecting the change in the average global temperature.

"The concept of how to reduce global warming by reducing the use of energy that causes toxic gases and smoke that cause harm to humans and living things"

(Student 43718).

"Global warming is making life difficult for living things. The solution is to reduce global warming emissions and reduce pollution from planting replacement forest plants"

(Student 43700).

"Reducing air pollution by reducing energy from fossils and mass transportation"

(Student 43848).

Students can identify all three components of scientific explanation, as shown in the example below. For example,

"Reducing air pollution emissions enables humans and living beings to live a long life (claim). Car factory emissions and burning waste (evidence). Emissions from industrial plants and automobiles result in polluted air and cause global warming (reasoning)"

(Student 43869).

During learning activity, students were asked to identify each component of scientific explanation of their own group and the other groups. This is a repetitive practice which gives students to understand and identify the differences between claim, evidence and reasoning, as shown from the test result of scientific explanation ability in Table 4.

2. The results of the comparison of the students' scientific explanation ability before and after learning with the science drama-based learning are shown in Table 4. The scientific explanation (SE) ability after learning with the science drama-based learning was higher than before learning. It was statistically significant at the .01 level ($t = 8.28$, $p < .01$) classified by the scientific explanation components in each aspect as follows: Claim after learning was higher than before learning with the statistical significance at the .01 level ($t = 5.52$, $p < .01$). Evidence after learning was higher than before learning with the statistical significance at .01 level ($t = 8.93$, $p < .01$). And, Reasoning after learning was higher than before learning with the statistical significance at the .1 level ($t = 6.84$, $p < .01$).

3. The results of the study on the satisfaction of eleventh-grade students towards the science drama-based learning.

The satisfaction level of 22 eleventh-grade students in Nakhon Pathom province towards the science drama-based learning was at the highest level. The mean score was 4.53 and the standard deviation was 0.59, with the order of satisfaction from highest to lowest in each aspect, respectively, as follows: Aspect of promoting application in daily life, aspect of promoting cognition and thinking skills, and aspect of learning management and scientific attitudes. Details are shown in Table 5.

Table 4 The results of comparison of the mean scores on the students' scientific explanation ability before and after learning with the science drama-based learning.

Results	*n*	$\bar{x}$	*SD*	*t*	*p*
The scientific explanation ability (after learning)	22	41.27	9.81	8.28	.000**
The scientific explanation ability (before learning)	22	25.41	10.57		
Claim (after learning)	22	15.14	3.08	5.52	.000**
Claim (before learning)	22	11.41	3.02		
Evidence (after learning)	22	13.86	3.20	8.93	.000**
Evidence (before learning)	22	7.18	3.74		
Reasoning (after learning)	22	12.27	4.32	6.84	.000**
Reasoning (before learning)	22	6.82	4.62		

Note: $^{**}p < .001$.

Table 5 The results of the study on the satisfaction of eleventh-grade students towards the science drama-based learning.

Aspect	Satisfaction (n = 22)		
	$\bar{x}$	*SD*	Meaning
1. Aspect of learning management and scientific attitudes			
1. Using science dramas as an appropriate method for organizing science learning	4.34	0.51	Good
2. Learning science subjects by using science dramas is fun and challenging.	4.30	0.59	Good
3. Science drama performances stimulate interest in learning science.	4.21	0.63	Good
4. Science dramas promote good attitudes towards science subjects.	4.65	0.66	Excellent
2. Aspect of promoting cognition and thinking skills			
1. Science drama performances promote knowledge and understanding of science content.	4.34	0.55	Good
2. Science drama performances help students learn in a systematic and step-by-step manner.	4.43	0.59	Good
3. Science drama performances promote analytical thinking and creativity.	4.60	0.67	Excellent
4. Science drama performances develops personality and communication abilities.	4.69	0.59	Excellent
3. Aspect of promoting application in daily life			
1. Science drama performances encourage students to use scientific data to support their own opinions and conclusions.	4.52	0.67	Excellent
2. Science drama performances promote teamwork.	4.91	0.45	Excellent
3. Science drama performances help students apply scientific knowledge to other subject content.	4.65	0.65	Excellent
4. Science drama performances help students apply scientific knowledge in everyday situations.	4.69	0.58	Excellent
Total	4.53	0.59	Excellent

Discussion

The scientific explanation ability after learning with the science drama-based learning was higher than before learning. It was statistically significant at the .01 level (t = 8.28, p < .01) classified by the scientific explanation components in each aspect as follows: Claim after learning was higher than before learning with the statistical significance at the .01 level (t = 5.52, p < .01). Evidence after learning was higher than before learning with the statistical significance at 0.01 level (t = 8.93, p < .01). And, Reasoning after learning was higher than before learning with the statistical significance at the 0.01 level (t = 6.84, p < .01). And, the satisfaction level of students towards the science drama-based learning. The overall satisfaction was at the highest level. (Mean is 4.53, and the standard deviation is 0.59). Previous research on the science drama-based studies reflected that creating and playing science drama keep students interested in studying science, understanding scientific concepts, and scientific attitudes (Abed, 2016; Maharaj-Sharma, 2017; Najami et al., 2019). This research shows that the science drama model could drive the development of the scientific explanation ability through the science drama-based learning process (referring to student's drama data). Discussions were held on the issues that led to drama and reflection continuously, following the steps below: Step 1: Orienting and Questioning; Step 2: Investigating; Step 3: Strengthening Understanding/Reflecting; Step 4: Developing the Drama and Step 5: Communicating/Reflecting. From the research results, it was found that students could develop the scientific explanation ability based on the scientific explanations components of claim, evidence, and reasoning. However, students still need encouragement in evidence section and reasoning section with learning and teaching by integrating scientific explanation component with science content. Importantly, this research reflected that the score in the reasoning section is not as high as it should be, compared with other scientific explanation components. The results of this research are consistent with previous findings. It highlights the issue of explaining the relationship between evidence and claims (or conclusions). The citation of sufficient and appropriate evidence for a claim (or conclusion) and the student's difficulty in determining the scientific reasoning was consistent with the data or evidence and the claim (or conclusion), as well as, the ability to communicate to others to understand in its entirety. (Kuhn & Reiser, 2005; McNeill & Krajcik, 2011; Sandoval & Millwood, 2005). It was consistent with Patterson (2001), who said that learners had difficulty writing scientific descriptions because they could not communicate their thoughts in the form of writing a text description.

Conclusion and Recommendation

1. Promoting the linkage of claim, evidence, and reasoning remains a crucial issue in the results of this research, similar to previous research. It is necessary to consider in detail the developed steps of the science drama-based learning activities in this research to strengthen students' scientific reasoning skills.

2. The research changed the format of science dramas performed by students to performed by animated characters instead according to the situation of the COVID-19 epidemic. Therefore, research issues that might be studied further are factors in bringing animated characters into the development of science dramas to compare the results with the students acting as real characters, which might affect the learning behavior of students further.

Conflict of Interest

The author declares that there is no conflict of interest.

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